ANATOMICAL NOTES ON THE LAND SNAIL *BOTHRIEMBRYON* (PULMONATA: BULIMULIDAE) FROM SOUTH AUSTRALIA AND WESTERN AUSTRALIA

by

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(Manuscript accepted 20 June 1985)

ABSTRACT

KERSHAW, R. C. 1986. Anatomical notes on the land snail *Bothriembryon* (Pulmonata: Bulimulidae) from South Australia and Western Australia. *Rec. S. Aust. Mus.* 19(16): 327-337.

Comparative notes on the anatomy of the South Australian land snail *Bothriembryon mastersi* (Cox, 1867) from different localities are presented. Comparisons are also made with *Bothriembryon barretti* Iredale, 1930 (Nullarbor Plain), *Bothriembryon melo* (Quoy & Gaimard, 1832) type of the genus (Western Australia), *Bothriembryon tasmanicus* (Pfeiffer, 1853) (Tasmania) and seven other Western Australian species. Features of the anatomy together with the protoconch sculpture of *B. mastersi* and *B. tasmanicus* suggest a clinal distribution pattern. Therefore the recognition of a subgenus *Tasmanembryon* Iredale, 1933 (Breure, 1979) is here suggested to be unjustified.

INTRODUCTION

Specimens of the snail *Bothriembryon mastersi* (Cox, 1867) collected by members of the Malacological Society of South Australia from St Francis Island (Nuyts Archipelago: 32°31'S, 133°18'E) and Venus Bay (33°11'S, 134°40'E) were dissected and compared with specimens of this species from Port Lincoln and Flinders Island, South Australia.

Study of the Nullarbor Plain species *Bothriembryon barretti* Iredale, 1930 from two localities together with *Bothriembryon melo* (Quoy & Gaimard, 1832) (Albany, Western Australia), seven other Western Australian species and the Tasmanian species *Bothriembryon tasmanicus* (Pfeiffer, 1853) has enabled presentation of comparative notes on the anatomy and relationships within the genus.

SEM micrographs taken by Dr A. Solem of the Field Museum of Natural History, Chicago of the shell protoconch sculpture of *B. mastersi* and *B. tasmanicus* provide new information on the nature of this feature.

The recent evaluation by Breure (1979, pp. 91-96) of the status of generic level taxa suggested recognition of *Bothriembryon* Pilsbry, 1894 and *Tasmanembryon* Iredale, 1933 as subgenera on the basis of differences in the spermathecal duct and the protoconch sculpture. The anatomical and protoconch data presented in this paper permit further comment on the status of *Tasmanembryon*.

The holotype of *Bothriembryon mastersi* (Cox, 1867) described from Port Lincoln, Eyre Peninsula, South Australia, has not been located, but an apparent syntype from Flinders Island, 170 km to the north west within the Great Australian Bight, is preserved in the South Australian Museum (D.11341). The status of another Eyre Peninsula species *Bothriembryon angasianus* (Pfeiffer, 1864) which predates *B. mastersi* has yet to be determined; matter, however, beyond the scope of this paper. Full study on the South Australian species and their shells must depend on future research.

Very little has been published on the anatomy of *Bothriembryon*. Early comments and illustrations of genitalia and buccal organs were presented by Semper (1870) and Hedley (1889). Pilsbry (1946) gave more detail and discussed the affinities of *Bothriembryon* with New World taxa. Breure (1978b, 1979) revising the Bulimulinae, has provided some descriptive and illustrative information. Breure (1978a) provided illustrations of part of the radula of both *B. melo* and *B. tasmanicus*.

The following abbreviations have been used in this paper: SAM, South Australian Museum, Adelaide; NMV, Museum of Victoria, Melbourne; TM, Tasmanian Museum, Hobart; QVM, Queen Victoria Museum, Launceston; FMNH, Field Museum of Natural History, Chicago; AE, anterior oesophagus; AG, albumen gland; BM, buccal mass; DI, digestive gland; E, prostate; EP, epiphallus; F, flagellum; GA, genital atrium; HD, hermaphrodite duct; I, intestine; KD, kidney; O, free oviduct; P, penis; PC, pericardium; PM, penial muscle; PV, pulmonary vein; R, rectum; RM, penial retractor; S, stomach; SD, bursa duct; SL, salivary gland; SO, spermoviduct; SP, bursa copulatrix; T, talon; U, uterus; V, vagina; VD, vas deferens; XB, site of bursa copulatrix.

MATERIALS AND METHODS

This work is based on study of more than 200 South Australian and 100 Western Australian specimens from the collections of the Museum of Victoria, the Tasmanian Museum and the Queen Victoria Museum. One "fossil" specimen of *Bothriembryon barretti* Iredale, 1930, collected by Miss Karen Gowlett at Petrel Cove, St Francis Island, 22 January 1982, from a sand

layer in the south-west cliff, is in Miss Gowlett's collection.

Selected Tasmanian specimens are included for comparative purposes from a study of *Bothriembryon tasmanicus* (Pfeiffer, 1853) (Kershaw, unpublished). The results from dissections presented are taken from the following material:

Bothriembryon mastersi (Cox, 1867)

St Francis Island, Nuyts Archipelago (32°31'S, 133°18'E); collected 24 January 1982 by K. Gowlett and R. Brown, 2 live and 12 dead specimens; deposited as follows: SAM D 17089, 1 spirit; D 17091, 6 dry specimens; QVM 1 spirit, 4 dry specimens.

Venus Bay, West Coast, Eyre Peninsula (33°11'S, 134°40'E); collected January 1982 by R. Brown, 14 live specimens; deposited as follows: SAM D 18090, 8 spirit specimens; QVM 6 spirit specimens.

Flinders Island, west coast Eyre Peninsula (33°43'S, 134°30'E); collected T. Castle, 6 March 1968, 5 spirit specimens; deposited: SAM D 17089.

Port Lincoln, Eyre Peninsula (34°44'S, 135°52'E) west side Spalding Cove; collected by B. J. Smith, 5 November 1969; NMV series spirit specimens.

Bothriembryon barretti Iredale, 1930

Wilson Bluff, Nullarbor Plain (31°40'S, 129°06'E); collected by T. A. Darragh, March 1969, deposited: NMV series spirit specimens.

Eyre Highway 44 miles east of SA-WA border (30°35'S, 129°20'E); collected by T. A. Darragh, 9 November 1973; deposited: NMV series spirit specimens.

Bothriembryon melo (Quoy & Gaimard, 1832)

Near Albany Western Australia (35°02'S, 117°43'E); 6 animals collected by G. W. Kendrick, 22 January 1972: author's collection courtesy S. Slack-Smith.

Bothriembryon bulla (Menke, 1843)

Clarence, Western Australia (and other localities); 8 specimens collected by G. W. Kendrick, 15 May 1971: T. M. Dartnall collection.

Bothriembryon glauerti Iredale, 1939

Bluff Knoll, Stirling Range north from Albany; 6 specimens collected by B. R. Wilson, 28 May 1971: T. M. Dartnall collection.

Bothriembryon indutus (Menke, 1843)

Walyunga National Park, Darling Range; 4 specimens: T. M. Dartnall collection.

Bothriembryon serpentinus Iredale, 1939

Bickley, Darling Range; 7 specimens collected by G. W. Kendrick, 10 July 1971: T. M. Dartnall collection.

Bothriembryon sayi (Pfeiffer, 1847)

Kudadup 200 m south of Jewel and Moondyne Caves, 8 km north of Augusta; collected by Anne Paterson, 6 July 1971; 6 specimens: T. M. Dartnall collection.

Bothriembryon leeuwinensis (Smith, 1894)

Kudadup near Jewel and Moondyne Caves, 8 km north of Augusta; collected by Anne Paterson, 6 July 1971: 6 specimens: T. M. Dartnall collection.

Bothriembryon kendricki Hill, Johnson and Merrifield, 1983

Booragoon west side of Blue Gum Swamp; collected by G. W. Kendrick, 13 June 1971; several specimens in T. M. Dartnall collection.

Bothriembryon kingii (Gray, 1825)

East of Wilson Inlet (35°00'S, 117°28'E); collected by R. C. Kershaw, 12 May 1978; 3 live and many dead specimens: QVM.

Bothriembryon tasmanicus (Pfeiffer, 1853)

Maria Island (42°38'S, 148°05'E); collected by R. H. Green, 1 May 1969: QVM.

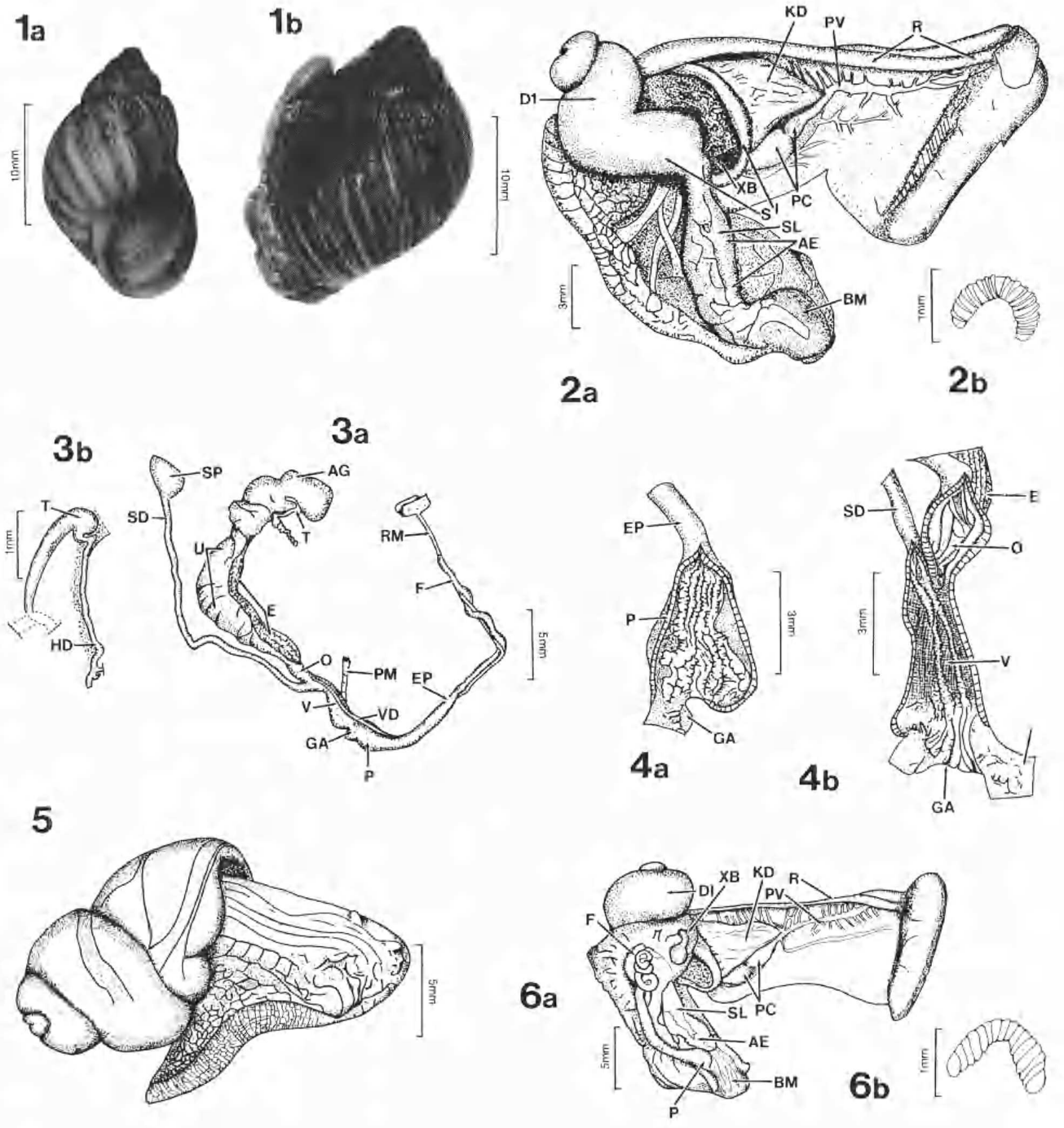
Cooks Beach (42°13'S, 148°18'E); collected by B. Moore, 27 May 1971: TM E 8914.

All dissections were done by the author using a Zeiss dissecting microscope and a Wild dissecting microscope with drawing arm. The drawings and photographs are by the author. Scanning electron micrographs were done by Dr Alan Solem (FMNH). The specimens selected from the listed collections, were coated with a 150 Angstrom units gold coating in a sputter coater and then studied with a Cambridge SR-10 stereoscan microscope. These specimens are stored as follows: St Francis I. and Venus Bay: QVM; Maria I.: QVM; Bicheno: TM E 13642; Near Eagle Hawk Neck: NMV.

The dissection data are presented on a species and locality basis within South Australia by comparison with *B. mastersi* from St Francis I. and between all other species and the South Australian species using the St Francis I. morph as the basic concept.

OBSERVATIONS

While the distribution of *B. mastersi* (Cox) is confined within South Australia that of *B. barretti* Iredale extends into Western Australia on the Nullarbor Plain. Both South Australian species have an elongate pallial structure (Figs 2, 6, 11, 17) which does not differ significantly from the generic features as described by Breure (1979). Each species has a pale orange jaw with 16 transverse ribs usually of darker orange colour (Figs 2, 17). Apart from gross size differences there are no important external body features requiring comment in this paper.



FIGS. 1-6. *Bothriembryon mastersi* (Cox, 1867); 1, shell: (a) St Francis Island (natural size 21 mm), (b) Venus Bay (natural size 17 mm); 2, St Francis Island, (a) pallial anatomy, (b) jaw; 3, St Francis Island, (a) whole genitalia, (b) detail of talon; 4, St Francis Island, (a) view of lower female tract, (b) internal view of penis; 5, Venus Bay, animal; 6, Venus Bay, (a) pallial anatomy, (b) jaw.

Bothriembryon mastersi (Cox, 1867)

Shell (Figs 1, 9)

Measurements of many specimens failed to reveal more than minor racial differences in the adult from the several localities. The sculpture and superficial appearance is as describd by Cox (1867) and Iredale (1937). The dimensions of shells from the dissected animals are presented in Table 1.

Protoconch (Figs 24a, b)

The sculpture is usually described as pitted or pit-reticulate. The optical microscope suggests ridges crossing obliquely. Anastomosing results in some irregularity of the pattern. Shells from Port Lincoln, Elliston, Wallanippie, Fowlers Bay, Streaky Bay, Venus Bay and St Francis I. provided minor differences. In some cases the basic wrinkled pattern as seen in *B. tasmanicus* can be seen near sutures.

Genital Anatomy

St Francis Island Material (Figs 3, 4).

Hermaphroditic duct thin, coiled, cream in colour, expanded slightly before entering the talon laterally.

Talon (Fig. 3b) 0.5 mm long, 0.3 mm wide, resting on albumen gland surface, then descending into albumen anteriorly to join with albumen gland duct and enter uterine passage. Albumen gland pale orange, ca 7 mm long. Spermoviduct with uterus translucent greyish amber in colour, prostate cream coloured slightly brownish near free oviduct. Latter short, 1.5 mm long, inflated, internally with wide fleshy ridges entering uterus. Vagina (Fig. 4a), ca 6 mm long, internally with broad low ridges just above atrium, apically becoming low rounded ridges crossed by transverse lines of pustules which continue as thin raised ridges into bursa duct. Free oviduct opening into bursa-vaginal channel is small and laterally oriented. Bursa duct ca 22 mm long, the bursa copulatrix 3×2 mm, somewhat globular, elongated and embedded above pallial apex next to albumen gland, kidney and digestive gland lobes.

Prostate narrowing to form thin, white tube of vas deferens (Fig. 3a) which emerges from free oviduct to vagina surface to atrial region then ascending partly free of penis to epiphallus to enter at base of flagellum. Latter short with a speckled grey surface. Chamber of penis (Fig. 4b) with 5 high subrounded folded longitudinal ridges modified into epiphallus. Atrium narrow with relatively very small lobes.

Dimensions and relative sizes presented in Table 2.

Venus Bay Material (Figs 5, 7, 8).

Apparently at a similar stage of maturity the anatomy closely resembles St Francis I. animal. Talon larger, 0.5 mm long, 0.5 mm wide, albumen gland less developed, 6.5 mm long of deep cream colour, uterus translucent pale yellowish cream. Free oviduct longer, 2.2 mm, vagina shorter, 4.5 mm. Internally the latter (Fig. 8a) has fine tightly folded ridges passing into bursa duct. Similar oblique lines of raised pustules are present.

Elongate globular bursa copulatrix appressed to uterine lobes (Fig. 6a) adjacent dorsal crop surface, not embedded as in the St Francis I. animal. This is the only instance observed of this nature in South or Western Australian animals and the degree of incidence or relationship to maturity is not known. The bursa duct coils through the uterine lobes normally.

The penial chamber (Fig. 8a) has 7 broad tightly folded longitudinal ridges abruptly very thin with epiphallus. Vas deferens appressed to penis-epiphallus throughout.

Dimensions and relative sizes presented in Table 2.

The complexly folded distinctly everted atrium has two large white lobes visible (Fig. 8b).

Flinders Island Material (Figs 14, 15).

A more mature larger animal (Fig. 14) with some differences (Table 2). Talon (Fig. 15b) large, 0.9 mm long, 0.6 mm wide, albumen gland ca 6 mm long greyish in colour, uterus translucent greyish but prostate as in St Francis I. animal. Free oviduct short, 1.5 mm with internal fleshy ridges, vagina short, 3 mm, with internal folds entering bursa duct as very fine close pustulose ridges. Bursa duct and bursa copulatrix as in St Francis I. animal.

TABLE 1. DIMENSIONS OF MALE AND FEMALE GENITALIA OF DISSECTED SPECIES (MEASUREMENTS OF MALE ORGANS AND SPERMOVIDUCT IN MM. PROPORTIONS OF FEMALE ORGANS EXPRESSED AS PERCENTAGE OF SPERMOVIDUCT).

Species	Male genitalia			Female genitalia			
	P	EP	F	SO	SD	O	V
	length			length	%	%	%
B. mastersi							
St Francis I.	3.0	20.0	3.5	24.5	90	6	24.5
Venus Bay	2.5	15.0	3.0	26.5	79	8	17.0
Flinders I.	2.5	10.5	4.5	31.5	70	5	9.5
Port Lincoln	2.5	14.0	3.0	21.0	81	12	15.0
B. barretti							
Wilson Bluff	10.0	14.0	9.0	28.0	128	11	12.5
Eyre Highway	8.0	13.0	7.0	31.0	123	13.5	10.0
B. melo	3.0	22.0	3.5	23.0	139	15	15.0
B. bulla	6.0	26.8	3.2	22.0	191	14	9.0
B. glauerti	6.0	28.0	16.0	30.0	180	7	13.0
B. indutus	3.5	18.5	10.0	32.5	111	9	5.0
B. serpentinus	4.0	16.0	11.0	23.0	61	9	6.5
B. sayi	2.0	8.0	8.0	22.0	82	7	7.0
B. leeuwinensis	6.0	27.0	10.0	42.0	100	6	5.0
B. kingii	10.0	17.5	4.5	31.5	83	11	13.0
B. tasmanicus							
Maria I.	5.0	19.0	6.5	19.0	53	8	13.0
Cooks Beach	5.0	26.5	9.0	21.0	81	14	10.0

Penis chamber ornament of broad flatly convex ridges variably folded similar to Venus Bay animal. The somewhat longer flagellum is normally very tightly coiled. Dimensions in Table 2.

Port Lincoln Material (Figs 12, 13).

Animal of similar size and maturity to St Francis I. specimen. Talon (Fig. 12b) 0.5 mm long, 0.4 mm wide, coloured pale cream, albumen gland 6 mm long, uterus translucent off white, free oviduct longer, 2.5 mm, than in the other animals but only 1.7 mm fleshy inflated.

Vagina, 3.2 mm, short as in Flinders I. animal, the internal pustulose ornament (Fig. 13) passing into the bursa duct which, at 17 mm length, is relatively longer than in the other animals.

Penial chamber ornament (Fig. 13) high rounded tightly folded ridges resembling the St Francis I. specimen.

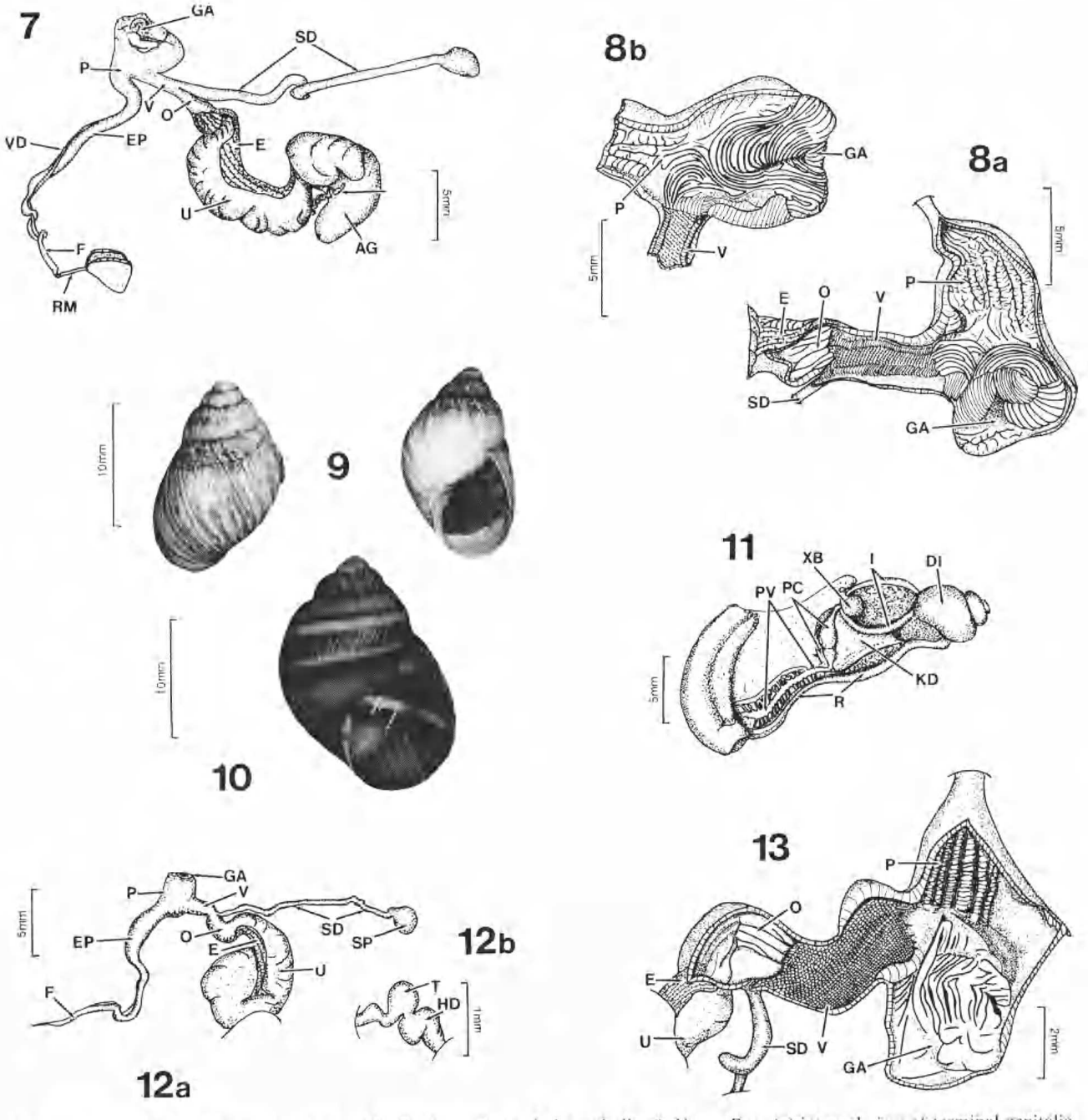
Dimensions and relative sizes presented in Table 2.

Bothriembryon barretti Iredale, 1930

Shell (Fig. 16)

This is a large species with a distribution on the Nullarbor Plain just west of Fowlers Bay in South Australia, possibly as far as Balladonia in Western Australia, 360 km from Eucla and Wilson Bluff at the border. The young shell has a very thin very pale brown epidermis usually lost in the adult. Descriptions are provided by Iredale (1930, 1937, 1939).

The "fossil" specimen (Fig. 16b) collected by Miss Gowlett on St Francis I. appears to be very similar to



FIGS. 7-9. *Bothriembryon mastersi* (Cox, 1867); 7, Venus Bay, whole genitalia; 8, Venus Bay, (a) internal view of terminal genitalia, (b) atrial complex, detail of folding; 9, Port Lincoln, shell (natural size 16 mm).

FIG. 10. *Bothriembryon angasianus* (Pfeiffer, 1864), Port Lincoln; shell (natural size 21 mm).

FIGS. 11-13. *Bothriembryon mastersi* (Cox, 1867), Port Lincoln; 11, pallial anatomy; 12, (a) terminal genitalia, (b) detail of talon; 13, internal view of terminal genitalia.

this species, the aperture proportions being almost identical with the holotype figure (Iredale 1930). The age of the specimen is unknown. Its appearance suggests early Recent (subfossil?) or possibly Late Pleistocene age. If correctly identified the range of the species formerly extended further east than is now apparent. The dimensions of this specimen and the shells of dissected animals are presented in Table 1.

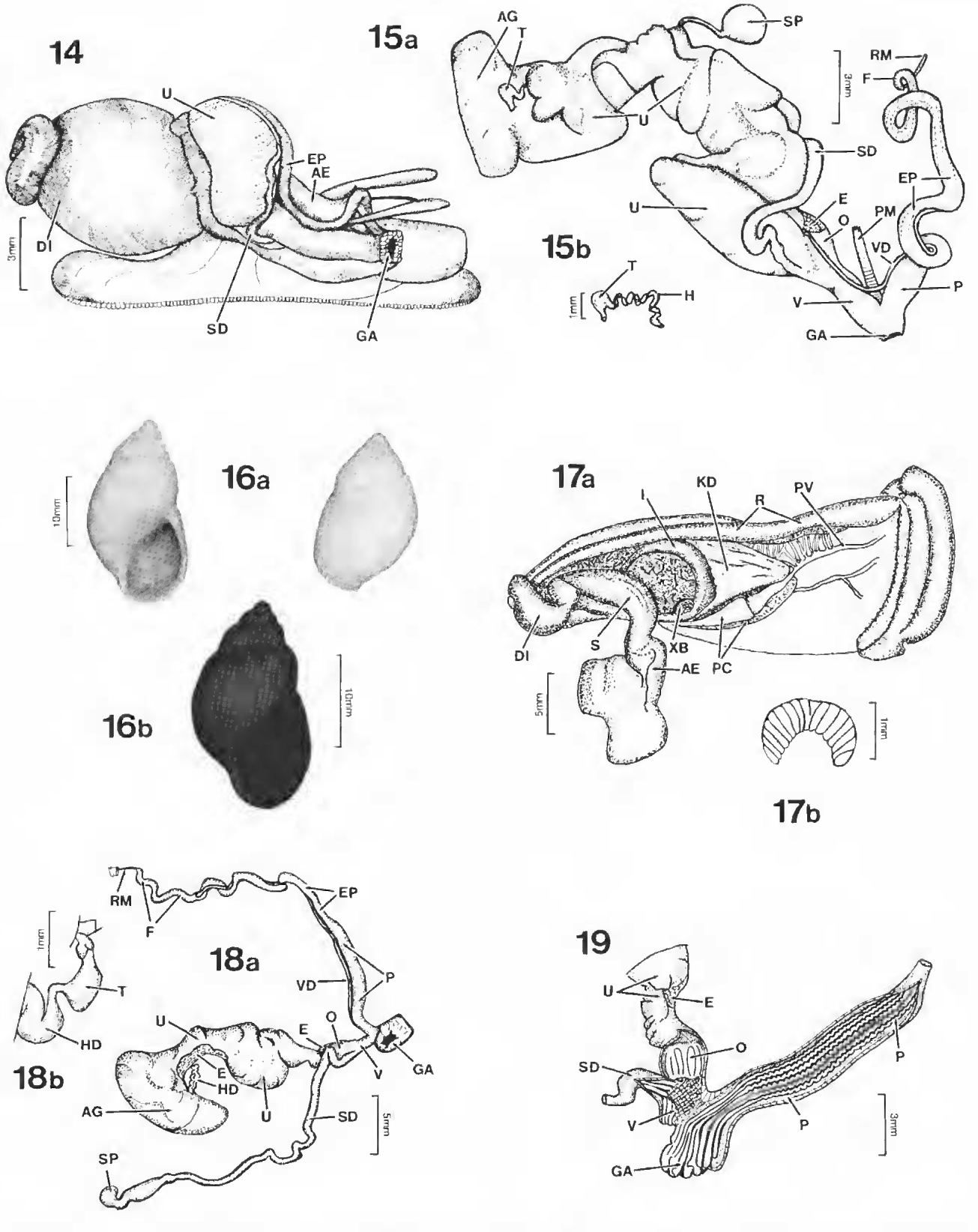
Protoconch

The optical microscope reveals radial oblique ridges crossed by vertical or oblique ridges resulting in somewhat squared pits. Descriptions (Iredale 1930) refer to pits not distinguished notably from *B. mastersi* (Cox).

Genital Anatomy

Wilson Bluff Material (Figs 18, 19).

Talon (Fig. 18b) somewhat elongate, 0.7 mm long, 0.4 mm wide, the elongate cream-coloured albumen gland ca 12 mm long, uterus translucent off-white, prostate cream. Free oviduct short, 3 mm, with internal swollen fleshy ridges through half the length, vagina



FIGS. 14-15. *Bothriembryon mastersi* (Cox, 1867), Flinders Island; 14, animal showing genitalia *in situ*; 15, (a) whole genitalia, (b) detail of talon.

FIG. 16. *Bothriembryon barretti* Iredale, 1930; (a) Wilson Bluff near Eucla (natural size 30 mm), (b) St Francis Island "fossil" (natural size 29.6 mm).

FIGS. 17-19. *Bothriembryon barretti* Iredale, 1930 Wilson Bluff; 17, (a) pallial anatomy, (b) jaw; 18, (a) whole genitalia, (b) detail of talon; 19, internal view of terminal genitalia.

(Fig. 19) slightly longer, 3.5 mm, with usual raised pustular ornament together with fine ridges entering bursa duct.

The bursa copulatrix is embedded above the pallial apex as in *B. mastersi* from St Francis I. (Fig. 2a) and Port Lincoln (Fig. 11) but the bursa duct is longer, 36 mm, not shorter than the spermoviduct.

Penis (Fig. 18a) very long, almost as long as epiphallus without a clear junction. The clearly constricted region (Fig. 19) between the atrium and penis, much more evident than in *B. mastersi*, is internally lined with thin folds. Penial chamber (Fig. 19) ornament bold rounded raised weakly folded ridges become thinner within epiphallus. The vas deferens emerges from free oviduct wall rather than at vagina junction as in *B. mastersi*, and is then appressed through to flagellum base. Flagellum, 9 mm, proportionately much longer than in *B. mastersi* (Table 2).

Eyre Highway Material (Figs 20, 21).

Talon (Fig. 20b) rounded. 0.6 mm long, 0.6 mm wide, with relatively short hermaphrodite duct entering 3 mm from apex, the narrowed exit duct passing deeply into pale cream-coloured 7.5 mm long albumen gland. Spermoviduct closely resembling Wilson Bluff animal but free oviduct shorter, 3 mm, vagina longer. Vas deferens (Fig. 21) within free oviduct narrows from prostate to form a ridge continuous with one of fleshy free oviduct ridges. Vagina (Fig. 21) internal pustular ornament is very close packed and becomes elongate entering the bursa duct. The latter, 34 mm long, is not coiled within the uterine lobes in the usual manner.

The penis-epiphallus dimensions are shorter than the Wilson Bluff animal but the proportions are similar.

Dimensions and relative sizes in both these animals are presented in Table 2.

Bothriembryon melo (Quoy & Gaimard, 1832)

Shell

This shell is clearly described by Kendrick & Wilson (1975) and no additional comment is needed. The genital anatomy is described on a comparative basis with dimensional data of this and other Western Australian species tabulated (Table 2).

Genital Anatomy (Figs 22, 23).

This specimen is considered representative of the several dissections made. Talon, 0.6 mm long, 0.5 mm wide, differs in appearance from *B. mastersi* with hermaphrodite duct entering relatively basally. Albumen gland short, ca 5 mm, cream-coloured, uterus very pale translucent greyish white, prostate very pale cream, free oviduct (Fig. 23), at 3.5 mm to 4.5 mm in length, relatively long with small fleshy ridges lining most of the chamber internally. Vagina (Fig. 23), 3.5 mm, short compared to St Francis I. *B. mastersi* but longer than some Western Australian species. The internal ornament of oblique irregular low elongate pustular lines becoming fine ridges in bursa duct, resembles *B. mastersi*.

Bursa duct (Fig. 22) much longer than spermoviduct but globular bursa copulatrix embedded exactly as in *B. mastersi* from St Francis I. (Fig. 2a) and Port Lincoln (Fig. 11).

Penis (Fig. 22) short, its chamber (Fig. 23) lined with about 6 close rounded folded ridges reducing in number and size within relatively long epiphallus. Vas deferens (Fig. 22) free from vagina surface in part and penis, becomes appressed at epiphallus. Penial complex proportions resemble those of *B. mastersi* but the oviduct and bursa duct are similar to *B. barretti* (Table 2).

The most significant feature noted in the other Western Australian species dissected is that the bursa duct length varies from 61% (*B. serpentinus*) to 191% (*B. bulla*) of the spermoviduct (Table 2).

Breure has figured the genitalia of *B. indutus* (Menke) (Darling Range) (1978a, Fig. 5; 1978b, Fig. 346), *B. glauerti* Iredale (Darling Range) (1978b, Fig. 345) and *B. onslowi* (Cox) (Shark Bay) (1978b, Fig. 350).

Bothriembryon tasmanicus (Pfeiffer, 1853)

Shell

Complete animal and shell descriptions will be presented elsewhere (Kershaw, unpublished). Selected dimensions are presented in Table 1.

Protoconch (Figs 24c-f).

The optical microscope reveals oblique wrinkles as noted by Breure (1979). Spiral lines were reported by Breure (1979, p. 95) but not by Pilsbry (1900, pl. 4). These spiral lines have not been detected in very many examples studied and their absence is supported by the micrographs figured. It is suggested that the spiral increment observed is due to the spirals observed in the adult sometimes having a visible origin usually low on the last protoconch whorl.

Genital Anatomy

The spermoviduct (Breure 1978a, Fig. 6; 1978b, Fig. 351) is broadly similar to the South Australian and Western Australian species. The essential differences are seen in the internal free oviduct and vagina ornament with fleshy glandular development greatly reduced in *B. tasmanicus*. The vagina has no pustular ornament and that of the free oviduct is distinct. The bursa duct is shorter than various Western Australian species and *B. barretti*, but it is not shorter than that of *B. mastersi* nor that of *B. serpentinus* (Table 2).

In Tasmania the range in length expressed as a proportion of spermoviduct length of 40% to 100%, can also include *B. savi* and *B. kingii*. These data were unknown to Breure (1979) whose Tasmanian material

TABLE 2. SHELL MEASUREMENTS (MM) OF SOUTH AUSTRALIAN AND TASMANIAN SPECIES

Species	Whorl Number	Height	Diameter	Aperture Height
B. mastersi (Cox)				
St Francis I.				
dissected sp.	4.75	15.2	11.3	10.1
largest seen	5.375	21.0	13.9	11.8
Venus Bay	4.75	16.8	12.1	10.1
Flinders I.	5.0	20.0	12.5	10.0
Port Lincoln	4.875	16.0	10.0	9.2
B. barretti Iredale				
Wilson Bluff				
dissected sp.	5.875	29.0	15.0	14.3
largest seen	6.00	31.2	16.8	16.0
Eyre Highway	5.75	24.1	14.4	14.2
St Francis I.				
fossil sp.	5.5	29.6	16.9	15.9
B. tasmanicus (Pfeiffer)				
Maria I.	4.75	22.4	13.7	14.1
Cooks Beach	4.75	21.0	12.5	13.0

came from Coles Bay. Six specimens from this locality have a mean of 53% of spermoviduct length.

The significant distinguishing feature of the female genitalia and spermoviduct is that the bursa copulatrix is always appressed to the uterus adjacent the base of the albumen gland. It is never embedded above the pallial apex as in the southern and Western Australian species. Only the one specimen from Venus Bay has any resemblance.

Compared with *B. melo* and *B. mastersi* the penis is longer and the internal penial ornament is not folded. The flagellum is longer than in those species but is comparable with *B. barretti* and other species (Table 2).

B. tasmanicus has a rounded pallial region compared with the elongate western forms. The shallow atrium has no constriction preceding the penial lumen. The species does form a very distinct entity but the features suggest a long period of isolation rather than consistent subgeneric features. Of the features used by Breure to define *Tasmanembryon* only the radula may be consistent.

DISCUSSION

The basic data on variation in the material studied are summarized in Table 1. Shell dimensions of the South Australian species are given in Table 2. The dimension of the largest specimen seen in each species is also given for comparison. From these data it can be seen that the shell of *B. mastersi* compare in size to *B. tasmanicus* but the aperture of the latter is nearer to *B. barretti*. Despite differences in shell height, however, there is surprising similarity in spermoviduct length. The most obvious differences are in the proportionate lengths of the bursa duct and secondly in the penial complex.

Genital Anatomy

B. barretti and *B. kingii* both have a much enlarged penis but the flagellum differs. *B. mastersi*, *B. melo*, *B. indutus*, *B. serpentinus* and *B. sayi* all have a small penis but the flagellum in the first two is rather short such as that found in *B. bulla*. *B. tasmanicus* and others tend to be intermediate. The bursa duct is significantly longer than other species in *B. barretti*, *B. melo*, *B. bulla* and *B. glauerti*.

The South Australian *B. mastersi* from the localities studied, has a duct length (mean of 80%) that is intermediate between the long ducts (mean 118%) of several Western Australian species (see also Breure 1978b, pp. 203-209; 1979, pp. 92-96) and the duct of *B. tasmanicus* (mean 63%). The length of the duct in the latter species varies considerably (Kershaw, unpublished) the range in different morphs as already noted being inclusive of that noted for *B. mastersi* and other species.

The South Australian *B. mastersi* is thus not strongly differentiated from the Western Australian species with which it shows clear affinity but could be part of a clinal gradient across southern Australia. More species need study to allow further evaluation of this theme; but the similarities observed in *B. tasmanicus* together with the relative dimensions given appear to support the concept.

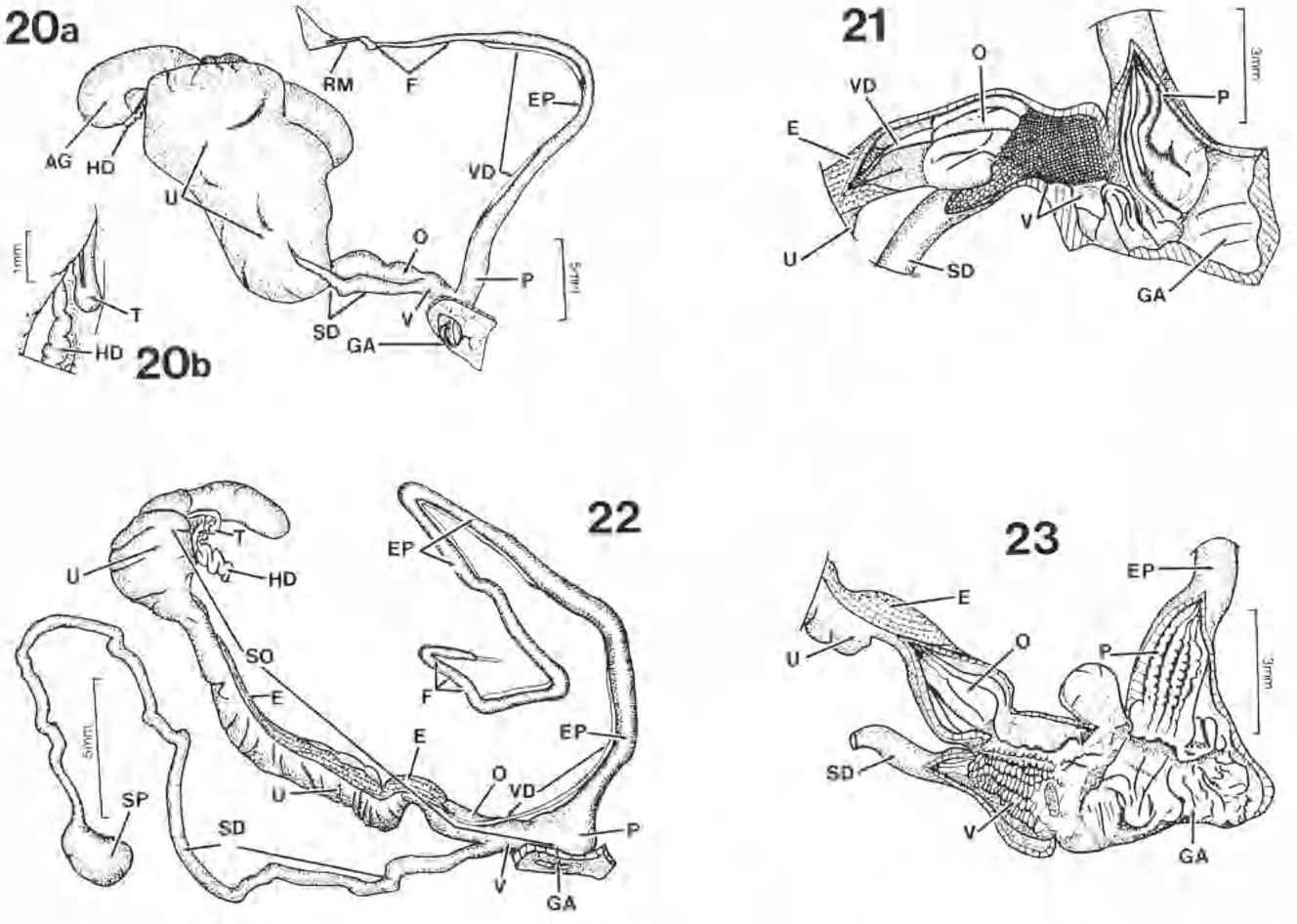
Protoconch

Few scanning electron micrographs have been published of bulimulid species. Breure (1978a, 1979, Pls 1-3) has provided several including *B. tasmanicus* and *B. onslowi* (Cox). He does not include micrographs of other genera he considers related to *Bothriembryon* nor does he expand on his data other than to separate *Tasmanembryon* from *Bothriembryon*. Since the structural details are complex, subject to change because of surface wear, and difficult to illustrate optically, more detailed study is desirable.

The photographs presented here of *Bothriembryon mastersi* and *B. tasmanicus* are the first to enable comparison both on a species and locality basis (Figs 24a-f) together with some different parts of the protoconch. Breure's (1979, Pl. 2) very useful work illustrated only part of one specimen of each of *B. tasmanicus* and *B. onslowi*.

The specimen of *B. mastersi* from Venus Bay is unworn, with both apical and post apical sculpture well defined (Fig. 24a). Note that the radial ribs on the apex are mostly continuous, with only a few anastomosing, or are interrupted along their length. In the worn specimen from St Francis Island (Fig. 24b) note that the apical sculpture is absent just above the periphery and the lower part of the first whorl has the sculpture worn down into minute "pits", although the typical sculpture can be seen on the right margin of the photograph. The post-apical sculpture is similarly degraded in comparison with that of Venus Bay specimen (Fig. 24a).

The specimen from Maria Island (Figs 24c, d), the probable type locality of *B. tasmanicus*, is unworn. The apical sculpture consists of generally continuous radial ribs with some anastomosing (Fig. 24d) at the sutures, while the post-apical sculpture is relatively inconspicuous on the upper spire. Another unworn specimen



FIGS. 20-21. *Bothriembryon barretti* Iredale, 1930 Eyre Highway; 20, (a) whole genitalia, (b) detail of talon; 21, internal view of terminal genitalia.

FIGS. 22-23. *Bothriembryon melo* (Quoy & Gaimard, 1832) Albany; 22, whole genitalia; 23, internal view of terminal genitalia.

from Bicheno (Fig. 24e) shows interruptions in the apical radials, more frequent anastomosing, and much more prominent early spire sculpture. A worn example from just north of Eagle Hawk Neck, south-eastern Tasmania, shows increased irregularity of the apical radials and more interruptions (Fig. 24f).

None of the Tasmanian specimens examined with the SEM show the spiral sculpture as claimed by Breure (1979, p. 92). It is possible that the points of irregularity visible (Figs 24e, f) in these specimens could be misinterpreted as spiral lines during optical viewing. The effect is noticeable above the suture in the Bicheno specimen (Fig. 24e). But Breure's figure of *B. tasmanicus*, presumably from Coles Bay, does show some trace of spiral joining of irregularity points on the lower part of the whorl (1979, pl. 2, Fig. 4). The possibility that adult spirals sometimes develop in the lower protoconch and sometimes do not has been suggested in comment on the species above.

In addition the illustration of *B. onslowi* (Breure 1979, Pl. 2, Fig. 3) shows traces of the irregular radials near the suture seen in some South Australian specimens. The apical sculpture is otherwise as seen in the western species.

Since the dissections reported on above show an apparent clinal variation in proportionate bursa duct length, and the SEM photographs of South Australian and Tasmanian species of *Bothriembryon* illustrate apical shell sculpture composed of the same basic elements rather than distinctive elements, the evidence does not support subgeneric distinction. Thus Breure's (1979) suggestion of subgeneric status for *Tasmanembryon* Iredale, 1933 requires further evidence if it is to be supported. The present evidence suggests that only one generic unit, *Bothriembryon* Pilsbry, 1894, is recognizable for the Australian Bulimulidae.

ACKNOWLEDGMENTS

This report was made possible by the provision of specimens from St Francis Island and Venus Bay for which gratitude is due to Miss K. Gowlett and Messrs N. J. C. Holmes and R. Brown. Gratitude is also due for specimens and loan of collections which contributed to the full study. Mrs Shirley Slack-Smith provided specimens of *B. melo* collected by Mr G. Kendrick and Mr Wolfgang Zeidler (South Australian Museum) loaned specimens from Flinders Island. Collections studied were provided by Dr B. J. Smith (Museum of Victoria), Miss Alison Green and Mrs E. Turner (Tasmanian Museum), Messrs C. B. Tassell and R. H. Green (Queen Victoria Museum). Dr A. J. and

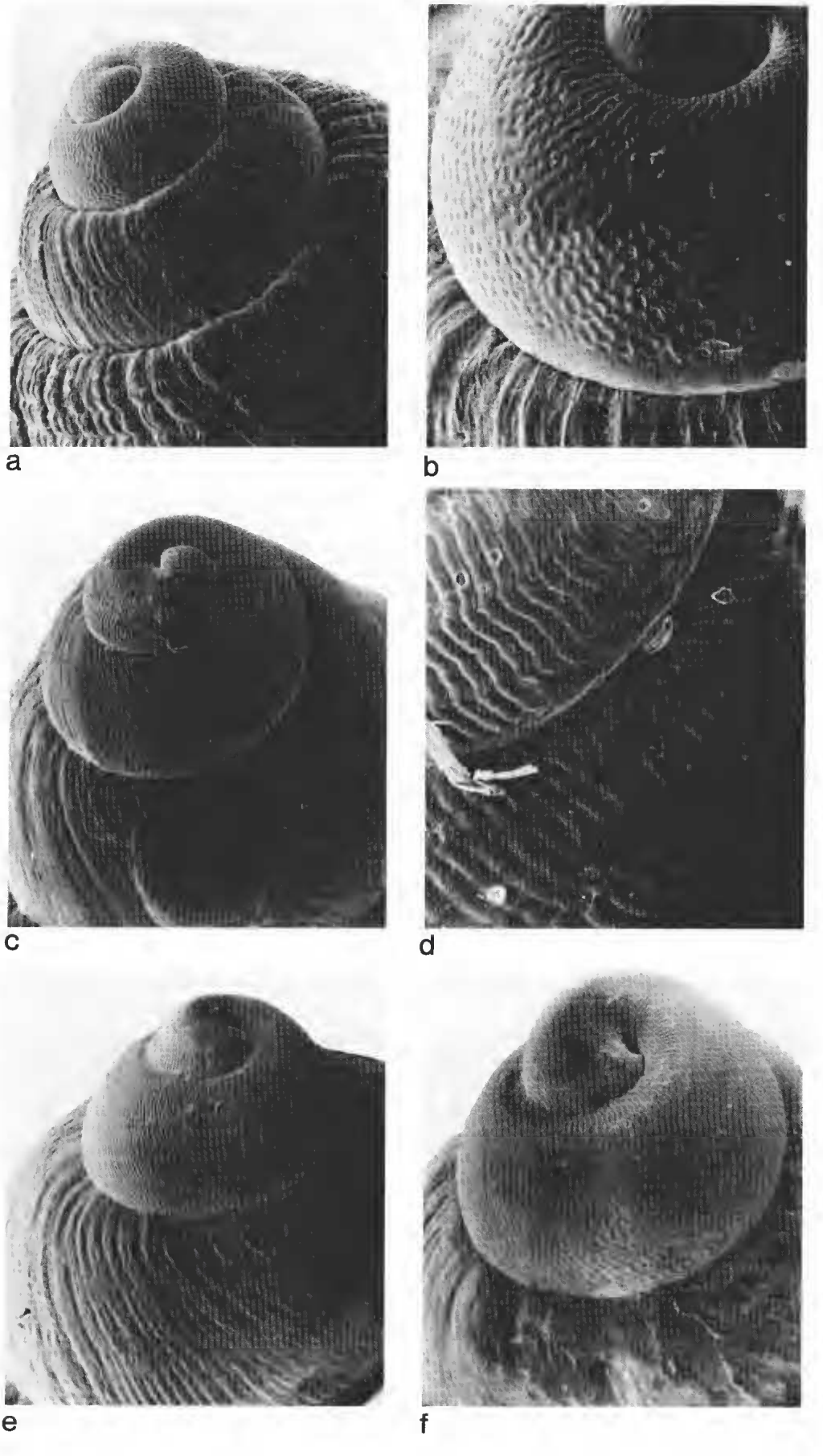


FIG. 24. Scanning electron micrographs of *Bothriembryon* apical sculpture. (a) *B. mastersi,* Venus Bay, whole apex × 15.7; (b) *B. mastersi,* St Francis Island, worn sculpture × 48.8; (c) *B. tasmanicus,* Maria Island, whole apex × 17.4; (d) *B. tasmanicus,* Maria Island, whole first stage × 88.5; (e) *B. tasmanicus,* Bicheno, whole apex × 18.1; (f) *B. tasmanicus,* near Eagle Hawk Neck, whole apex × 20.1.

Mrs J. A. Dartnall kindly made available material, drawings and manuscripts through the courtesy of the Tasmanian Museum.

Dr Alan Solem (Field Museum of Natural History, Chicago) made the SEM photographs used and provided very valuable discussion on the results. He also made valuable comments on earlier drafts of this manuscript and suggested an outline for the present approach. Dr Brian Smith provided many suggestions and discussion during the study and commented on the manuscript. Gratitude is due to reviewers for encouragement and some useful comment on presentation. The Science and Industry Endowment Fund has provided equipment and support critical to the success of my research for which gratitude is expressed to the Trustees.

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ADDENDUM

Since the above text was written Ludbrook (1984: pp. 301-302, Fig. 82) ("Quaternary Molluscs of South Australia". Department of Mines and Energy, South Australia, Handbook No. 9) has described and figured fossil *Bothriembryon barretti barretti* Iredale from the Semaphore Sand Formation and the Upper Member Bridgewater Formation. The St Francis Island specimen resembles her Figure 82a and b in form and boldness of sculpture, but appears to be an older specimen.